elegant:
A Flexible SDDS-Compliant Code
for
Accelerator Simulation

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Advanced Photon Source

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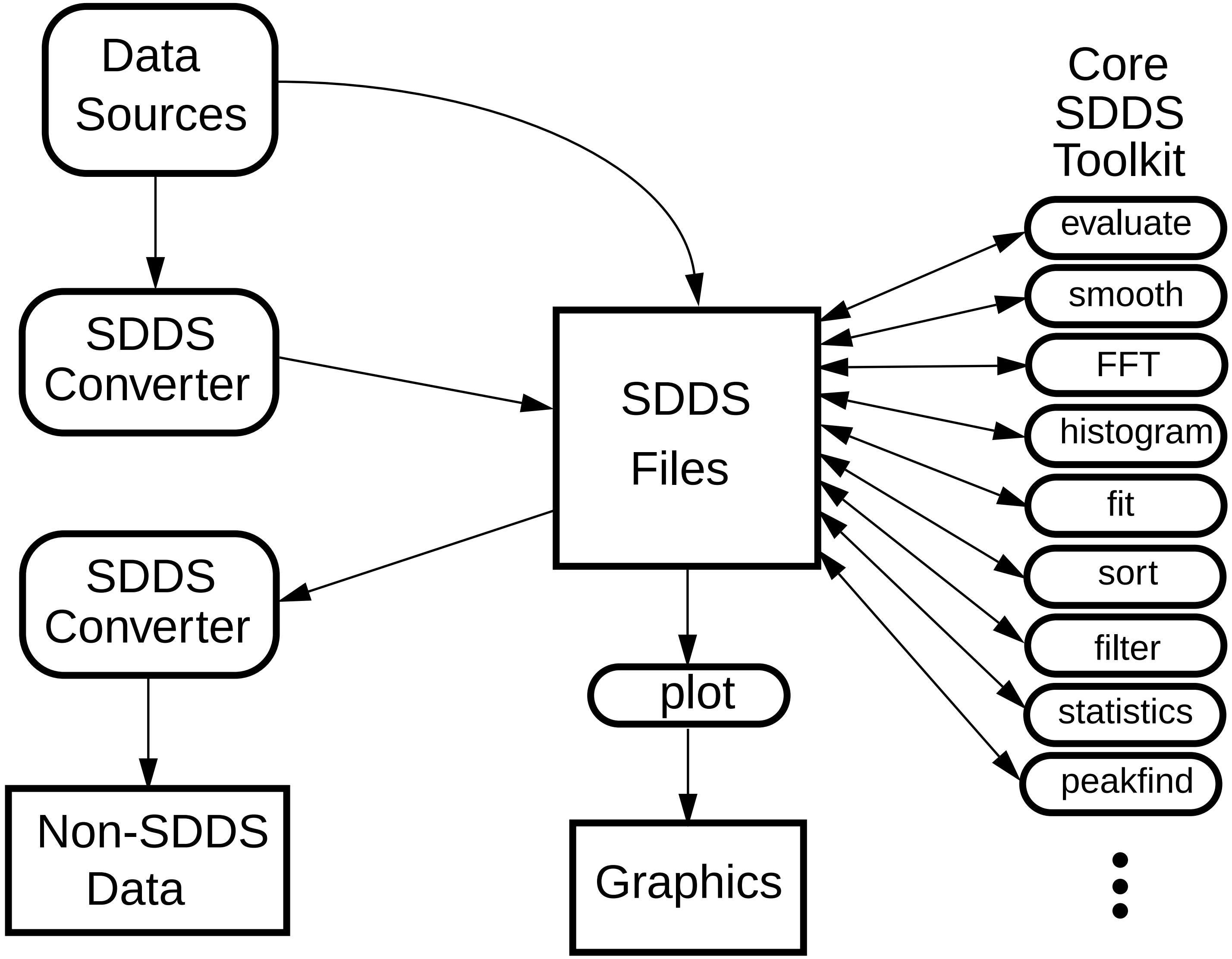
SDDS
Self Describing Data Sets

- An APS-developed file protocol and toolkit.
- Used with **elegant** and other simulations.
- Used by five accelerator laboratories for data archiving and control.
- ~70 general-purpose data analysis and display programs.
- Commandline-driven for easy use in scripts and automation.

SDDS Toolkit Paradigm



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General Capabilities of elegant
ELEctron Generation ANd Tracking

- Tracking single and multipass machines.
- Perturbation/variation of accelerator parameters.
- Orbit/trajectory computation and correction.
- Optics calculations and correction.
- Optimization of tracked and computed quantities.
- Dynamic aperture determination.
- Generation of macro-particles with various distributions.
- Macro-particle data to/from SDDS files.
- Copious SDDS output of results.

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Sampling of SDDS Output Files from elegant

- turn-by-turn particle coordinates
- turn-by-turn beam moments
- turn-by-turn histograms
- coordinates of lost particles
- beam moments vs. s
- transport matrix (up to 2nd order) vs. s
- Twiss parameters and radiation integrals vs. s
- lattice parameters (chromaticities, emittance, etc.)
- internally-generated error values

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Overview of Physics in elegant

- Track in 6D with matrices, canonical integration, numerical integration, or mixture.
- Time-dependent elements: rf cavity, rf deflector, kicker, traveling wave linac, etc.
- Collective effects: impedances, CSR, IBS*.
- SASE FEL computations.
- Collimators and scrapers.
- Quantum excitation*, radiation damping*, scattering.
- Misalignments.

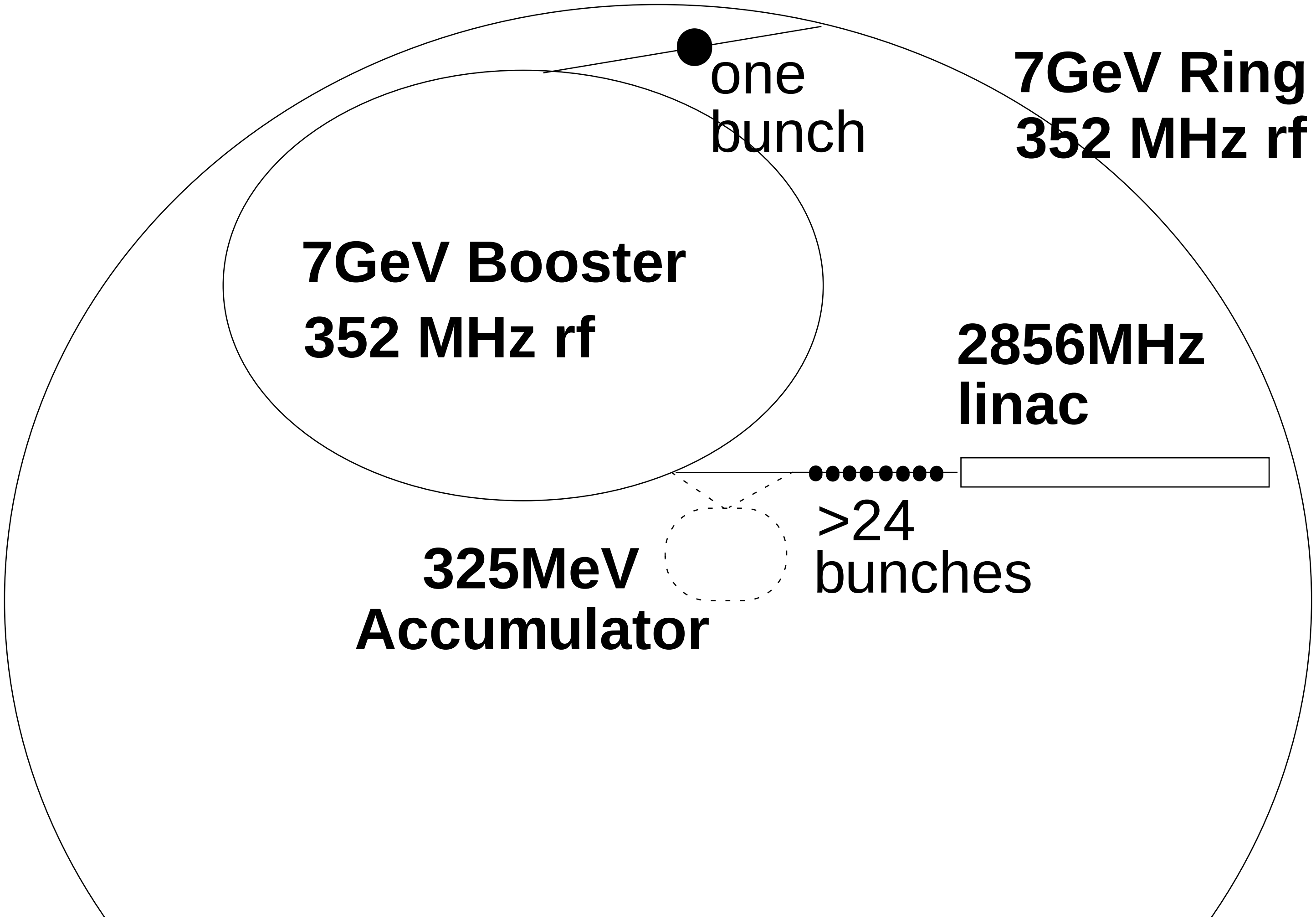
*rings only.

Some Accelerator Projects Accomplished Using elegant

- Tracking simulations for SSRL preinjector*
- Design of beamline for APS thermionic rf gun
- Design of APS Positron Accumulator Ring*
- Top-up safety tracking for APS storage ring
- Low-emittance lattices for APS storage ring
- Dual insertion device lattices for APS storage ring
- Design of APS bunch compressor and redesign of linac
- Sensitivity analysis and jitter simulation for LCLS

*Used MAD for matching.

Example:
Direct Injection from APS Linac to Booster



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Simulation Details

- generate 24 bunches at 2856 MHz
- provide linear energy ramp (SDDS file)
- provide $\sim E^4$ rf ramp (SDDS file)
- include radiation damping and quantum excitation
- gated vertical tune driver as bucket cleaner (SDDS file)
- run for 40 combinations of injection energy and initial rf voltage

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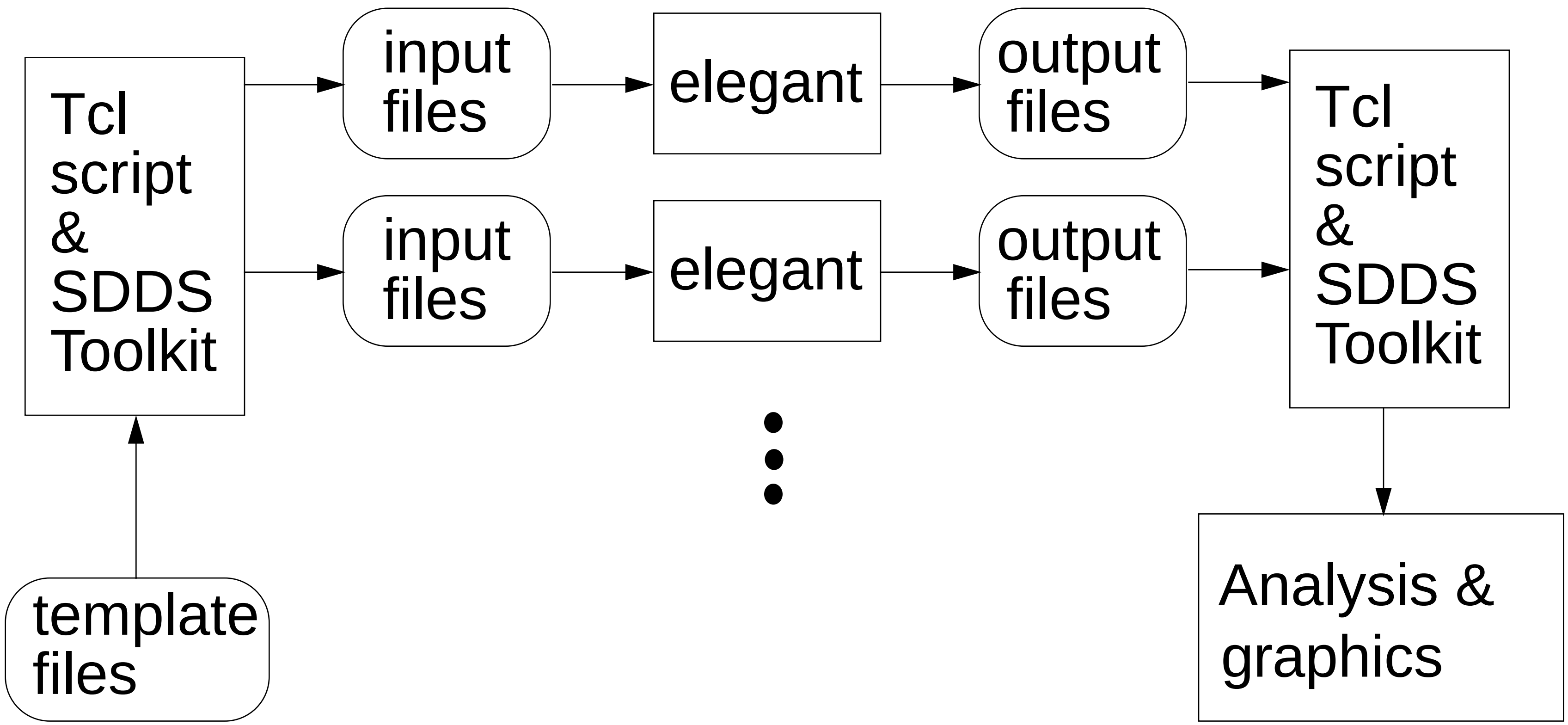
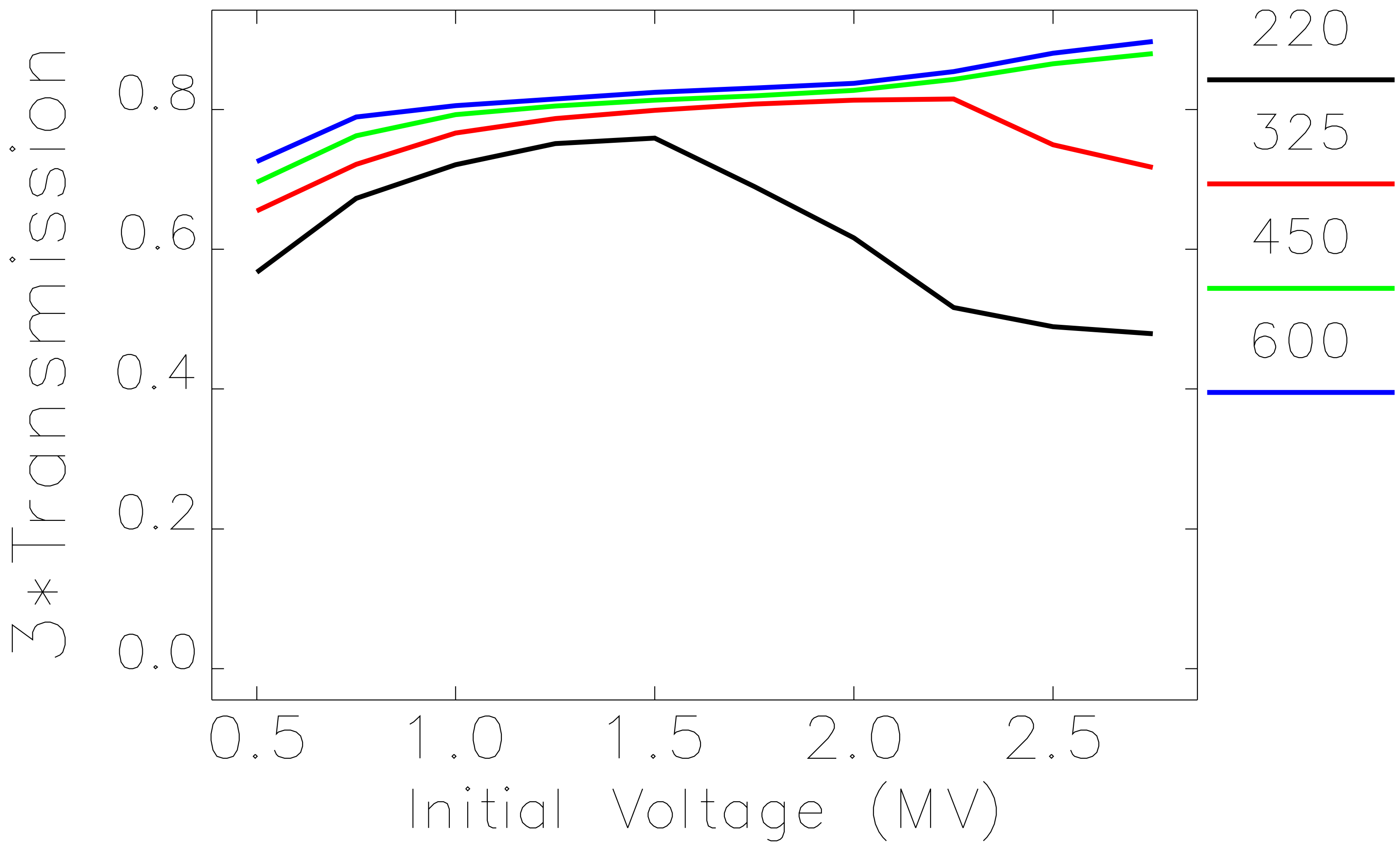
Organization of Simulations



Summary of Direct Injection Efficiency



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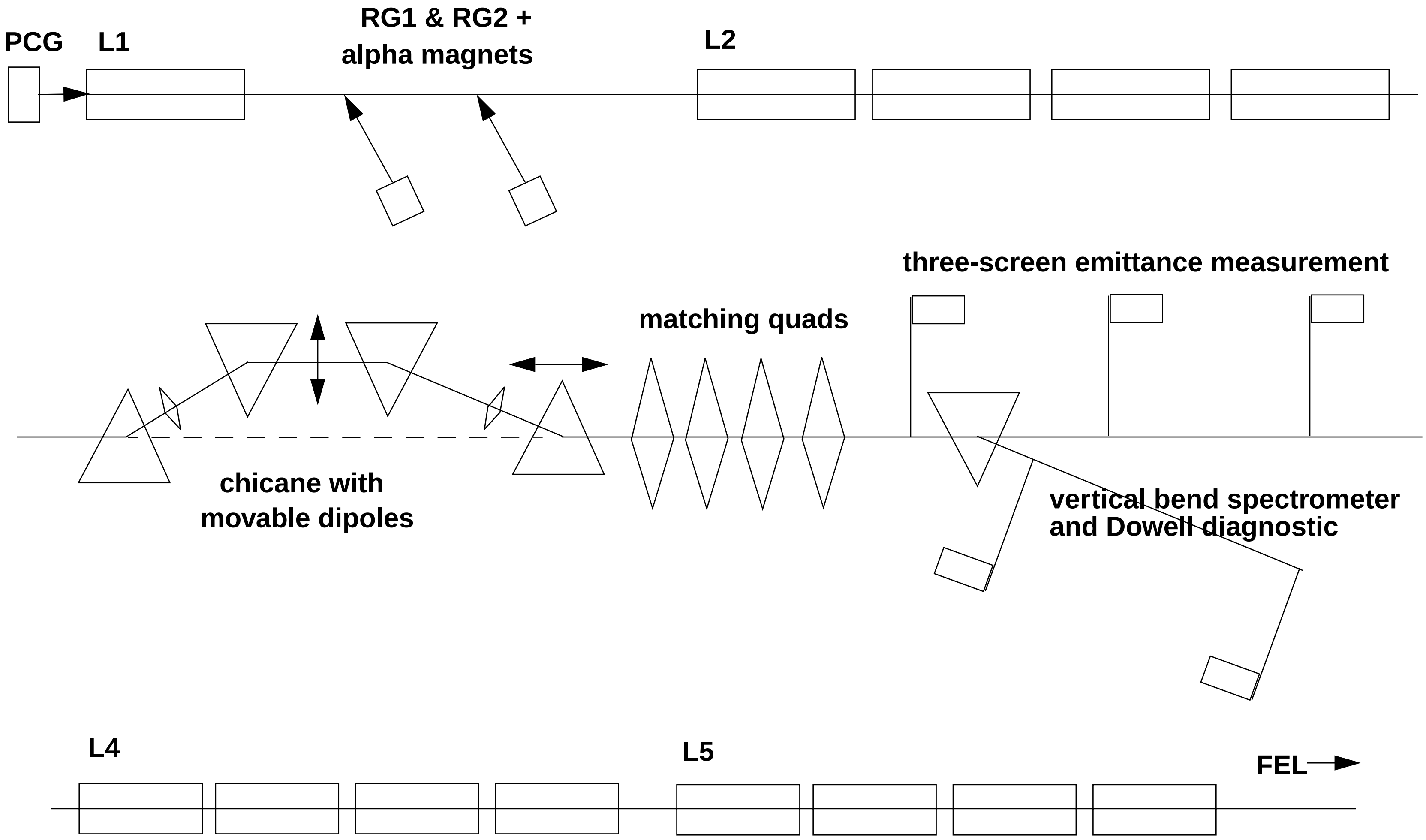
Example: APS Bunch Compressor Design

- Started in Summer 1999 as part of push to saturate LEUTL FEL.
- Secondary goal was to explore CSR.
- Design incorporates movable magnets to allow variable R_{56} and asymmetry.
- Short design and construction schedule benefitted from automation of simulation tasks.
- System in operation since late July 2000.

APS Linac/Compressor Schematic



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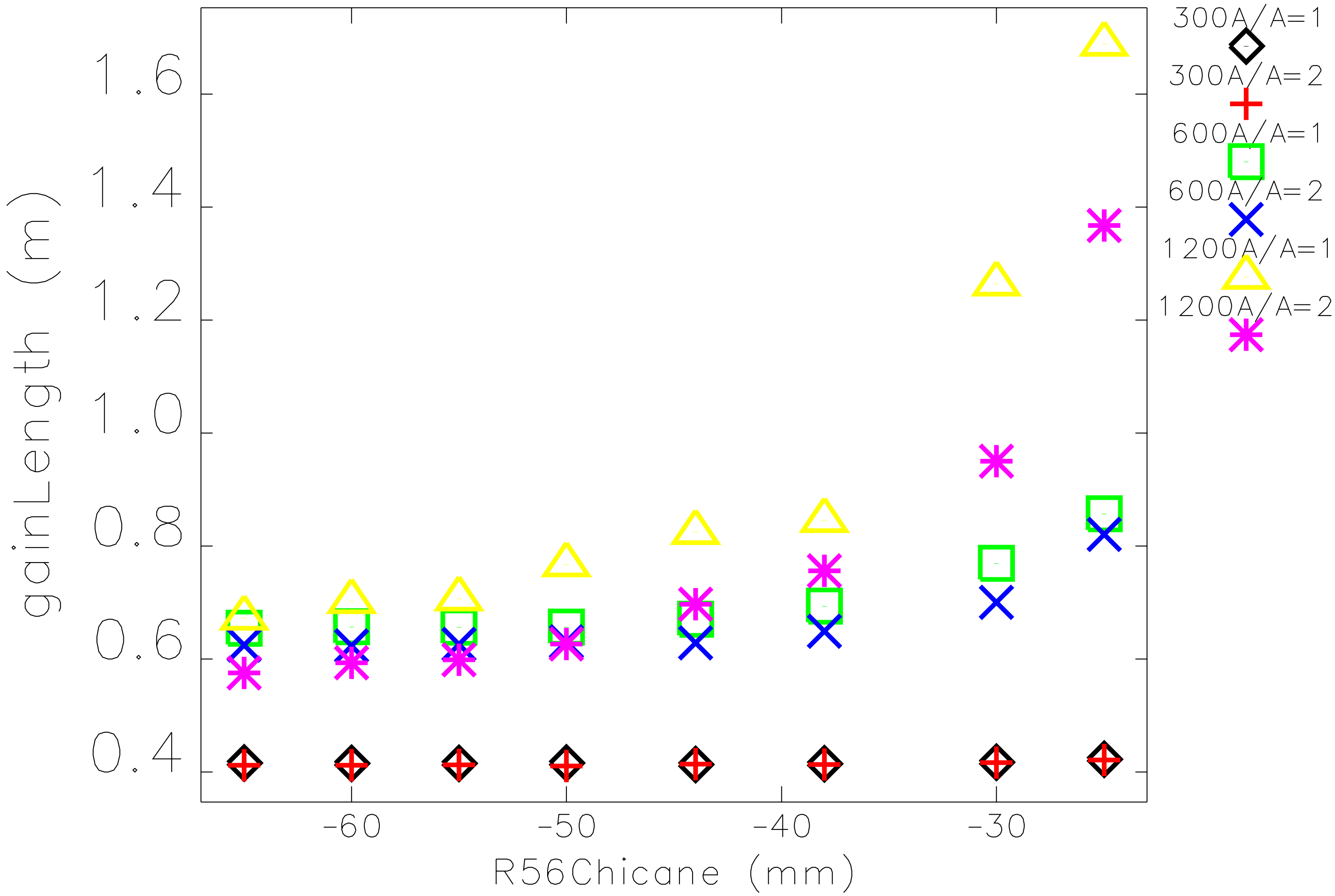
Simulation Tasks for APS Bunch Compressor

- Select a set of chicane configurations, i.e., R_{56} and asymmetry.
- Select target currents (e.g., 300A) and acceleration profiles.
- For each configuration
  - Perform longitudinal matching via tracking.
  - Perform transverse matching.
  - Track with wakefields and CSR.
  - Determine jitter sensitivity.
  - Track with random errors to verify tolerances.

What Was Accomplished with Bunch Compressor Simulations

- About 50 configurations were produced and examined in an automated fashion.
- Rapidly evaluated proposed (engineering) changes.
- Produced data for automated setup of accelerator.
- Found trends in emittance, gain length, etc. across a wide range of conditions.
- Found jitter sensitivity and identified least sensitive configurations.
- Produced tolerance requirements.
- Explored impact of relaxed tolerances.

Performance Variation Prediction



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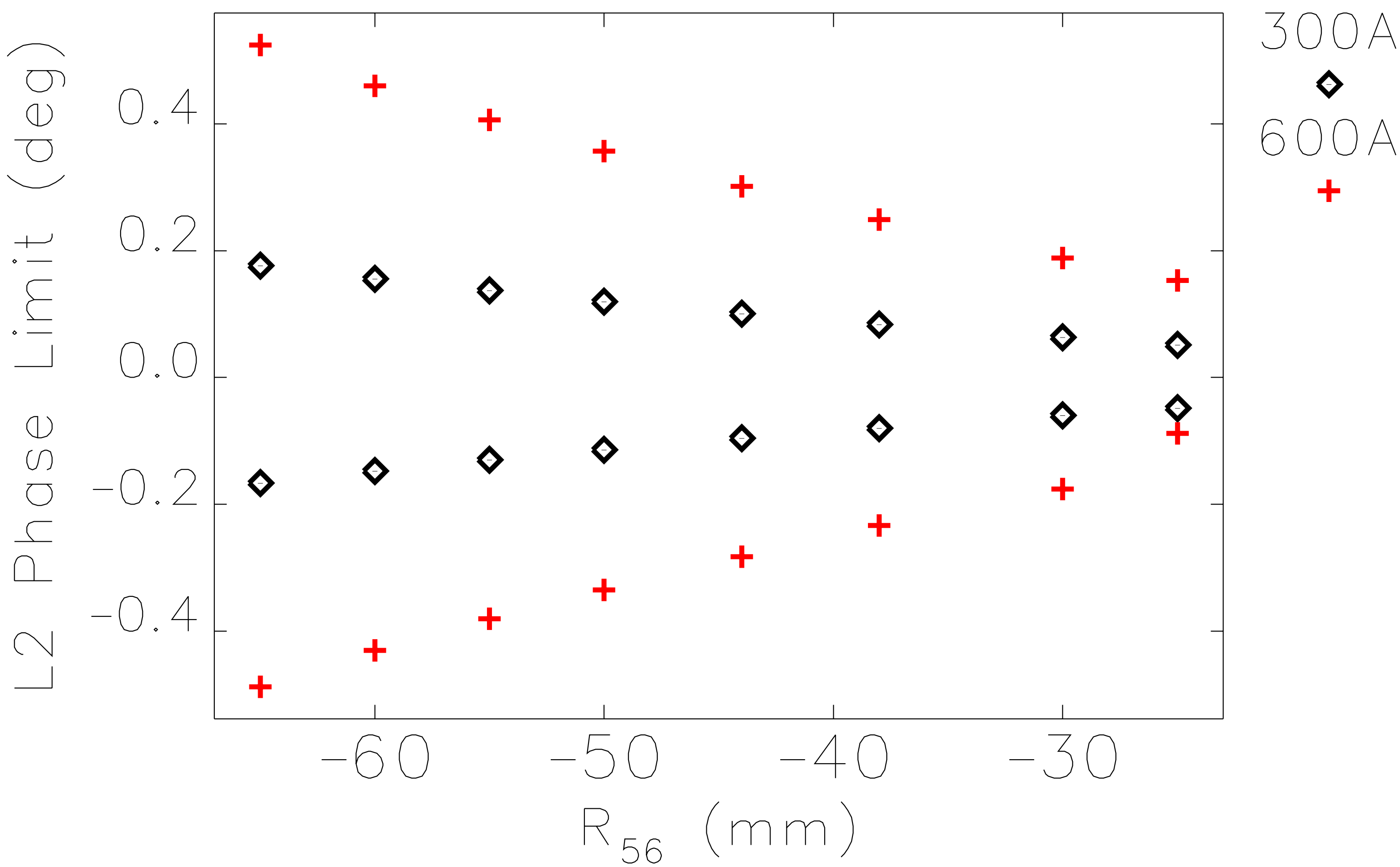
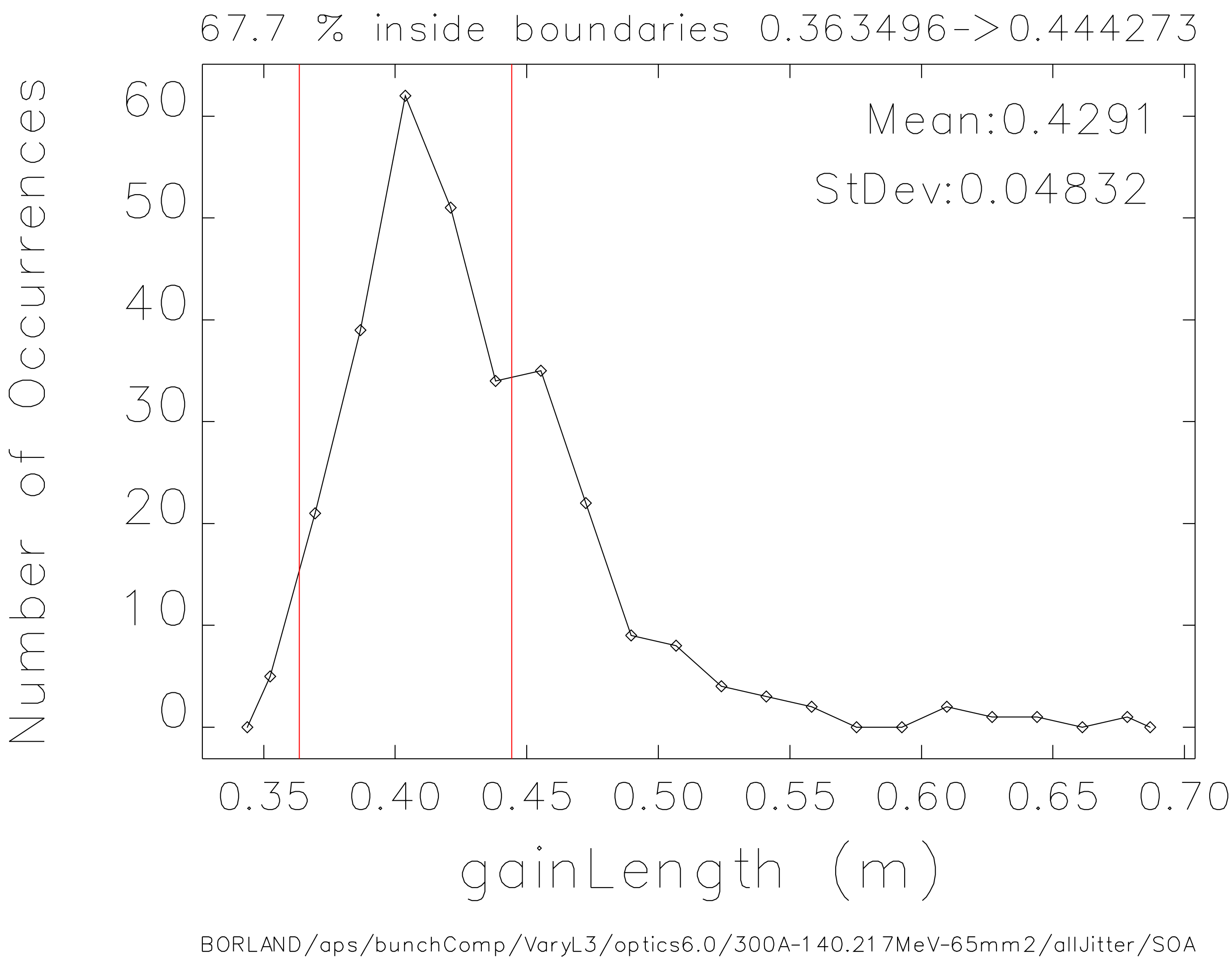
Phase Sensitivity Result



Sample Data from Jitter Simulation



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Summary

- **elegant** is a flexible code
  - well suited to complex projects
  - incorporating a wide variety of physics
  - incorporating unique features
  - applied to numerous real-world problems
- The SDDS toolkit
  - provides the sole pre- and post-processing software
  - enhances **elegant** dramatically